Annual Progress Report on "Biomass Burning and Emissions of Trace Gases and Aerosols: Validation of EOS Biomass Burning Products" – January 2002

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1. Objectives

The objectives of this project are to validate the NASA Terra satellite products of (1) aerosol optical thickness in smoke plumes; (2) radiative energy and the proportion of biomass burned in flaming and smoldering combustion; (3) locations of fires and sizes of burned areas; and (4) elevated concentrations of CO and CH_4 in smoke plumes. The MODIS instrument of the Terra satellite monitors aerosol optical thickness and the location and the size of fires. The MOPITT instrument measures CO and CH_4 concentrations. The regions selected for validation are Montana and Idaho for the 2000 fire season, continental U.S. for the 2001 fire season, and southern Africa during the SAFARI 2000 field campaign.

2. Progress

The major accomplishments of this project in the past year are summarized in the following sections.

2.1 Aerosol Optical Thickness during the SAFARI 2000 Campaign

Hazemeter AOT vs. AERONET AOT

Thirty-eight hazemeters, or handheld sun photometers, developed by the Forest Service were deployed in western Zambia between June 11 and Oct. 6, 2000. The instrument measures aerosol optical thickness at 880, 680, 530 and 380 nm. The measurement results in conjunction with the results from the AERONET automatic sun photometers were used to validate aerosol optical thickness measured by the MODIS instrument. Table 1 summarizes the spectral bands of the three instruments.

Table 1: AOT Instrument Bandpasses

Hazemeter Band (nm)	AERONET Band (nm)	MODIS Band (nm)
880 (850-905)	870	865 (841-876)
680 (680-690)	670	659 (620-670)
530 (510-550)	500	550 (545-565)
380 (360-410)	380	No match

We compared the measurement results between Forest Service hazemeters and AERONET sun photometers at these four bands in Zambezi, Ndola, Mongu, Mwinilunga, and Kaoma. The results are summarized in Figs. 1-4 and Table 2.

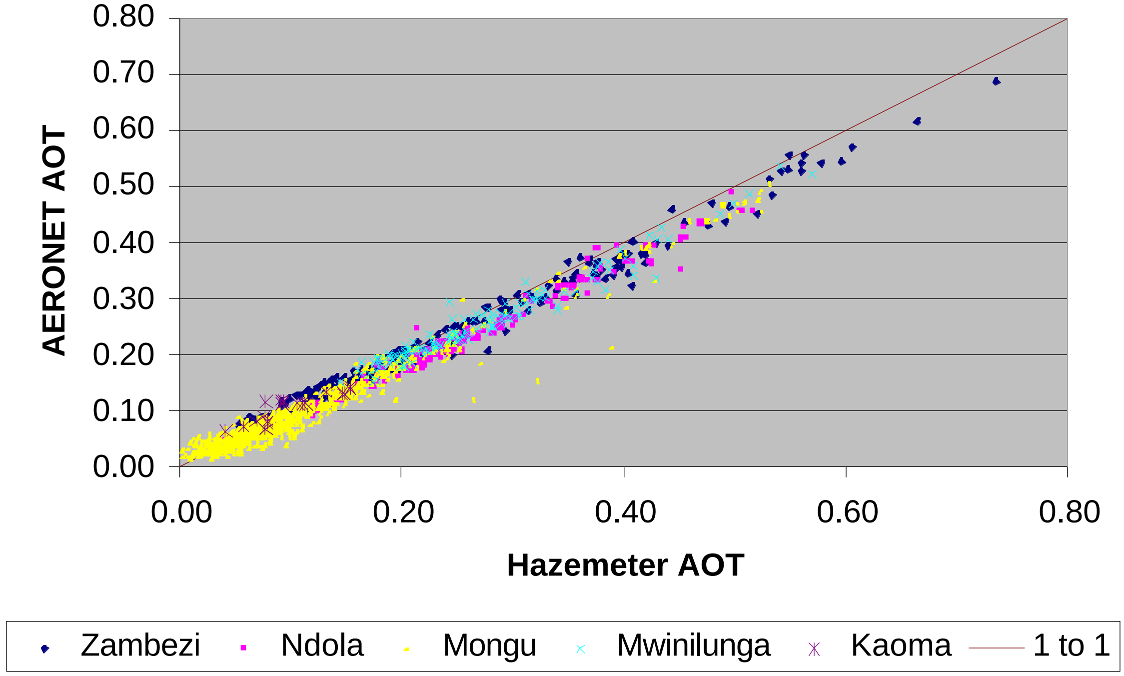


Fig. 1. 880/870 nm AOT Comparison

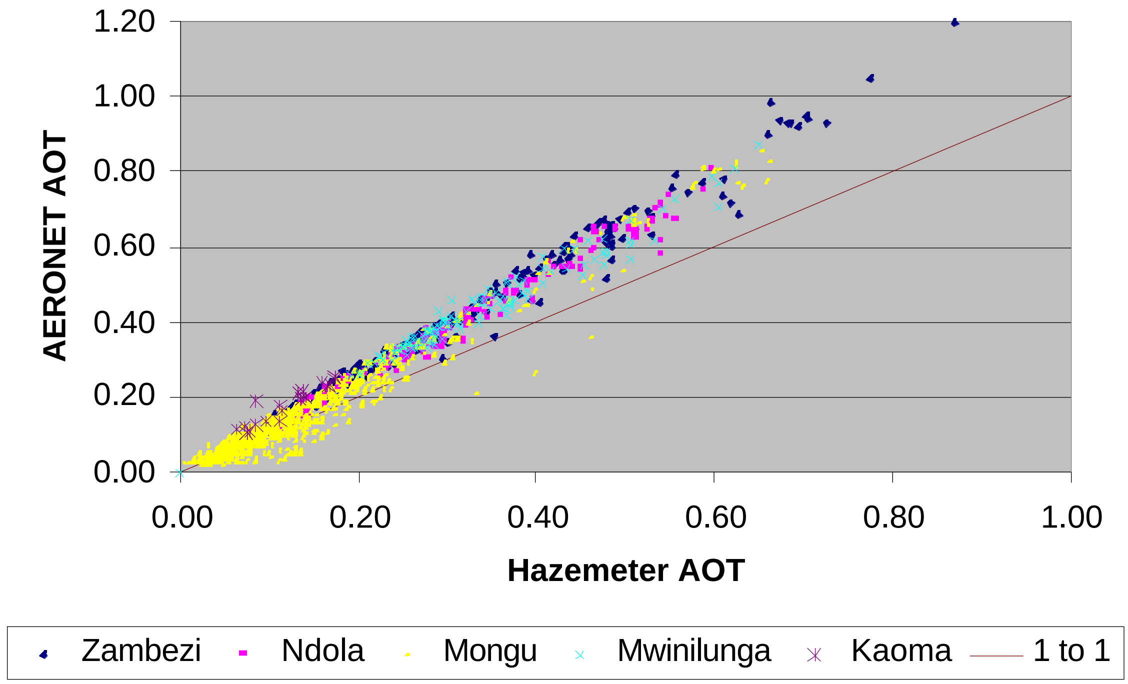


Fig. 2. 680/670 nm AOT Comparison

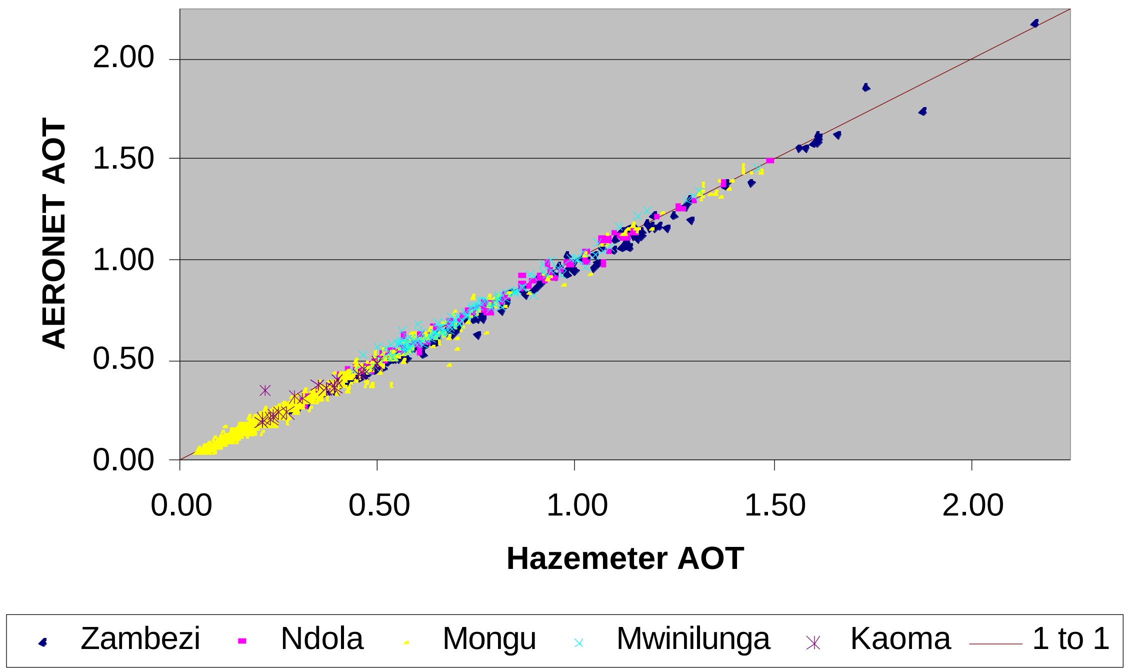


Fig. 3. 530/500 nm AOT Comparison

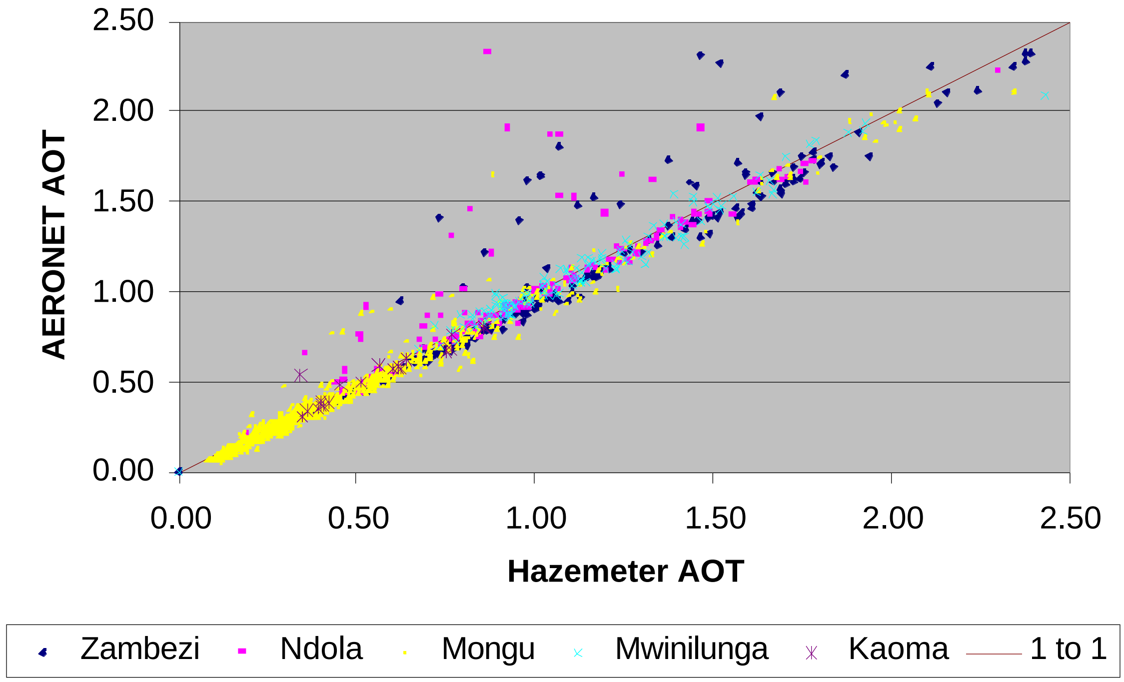


Fig. 4. 380/380 nm AOT Comparison

Table 2. Linear relationships between hazemeter data and AERONET data

Band (nm)	Slope	Intercept	RMS Error	R^2
880 vs 870	0.918	0.00105	0.0162	0.979
680 vs 670	1.310	-0.0138	0.0295	0.976
530 vs 500	0.995	-0.0121	0.0240	0.995
380 vs 380	1.003	-0.0223	0.1112	0.946

The measurements at 880/870 and 530/500 nm have excellent agreement for the two instruments with a slope close to 1. Although the measurements at the 680/670 nm band are linearly correlated (R^2 = 0.976), the hazemeter measurements are about 34% lower than the AERONET sun photometer measurements. The differences may be caused by inaccurate calibration of hazemeters or differences in spectral responses. The 380/380 band measurements are linearly correlated for the two instruments (R^2 = 0.946) with a slope of 1.0, except that some AERONET data are higher than the hazemeter data in Zambezi and Ndola.

MODIS AOT vs. Hazemeter AOT

We compared aerosol optical thickness data measured by the MODIS instrument and the hazemeters at 680/659 nm and 530/550 nm bands. The version 3 MODIS AOT data were retrieved from the USGS EROS Data Center DAAC. The results are shown in Fig. 5. The hazemeter AOT data at 680 nm have been corrected using the linear relationship between AERONET and hazemeter data.

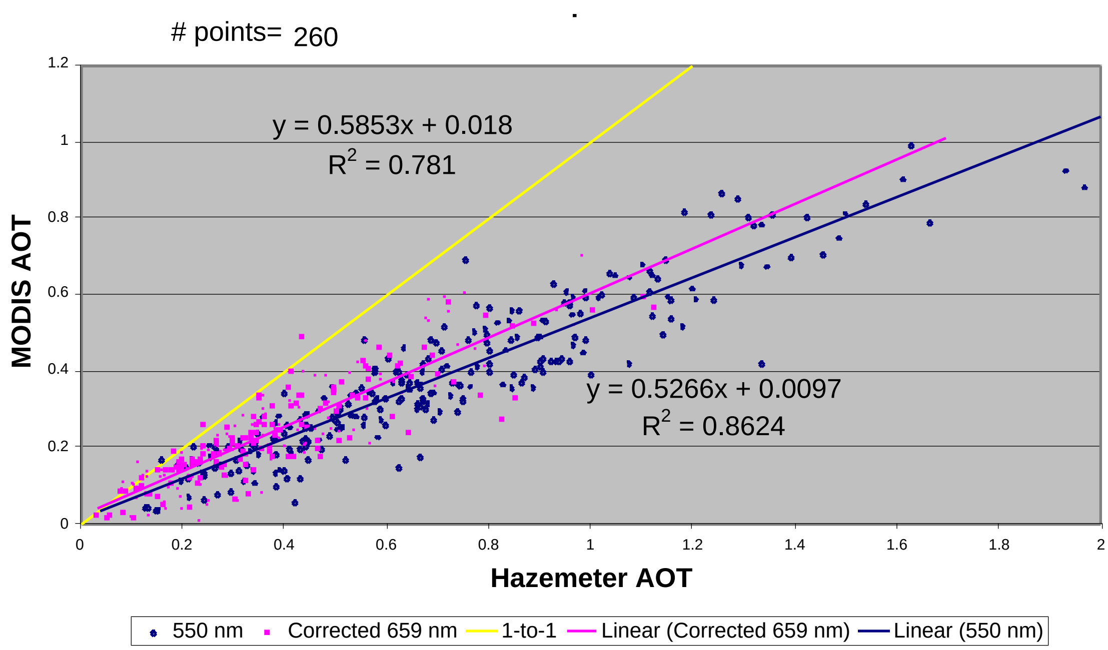
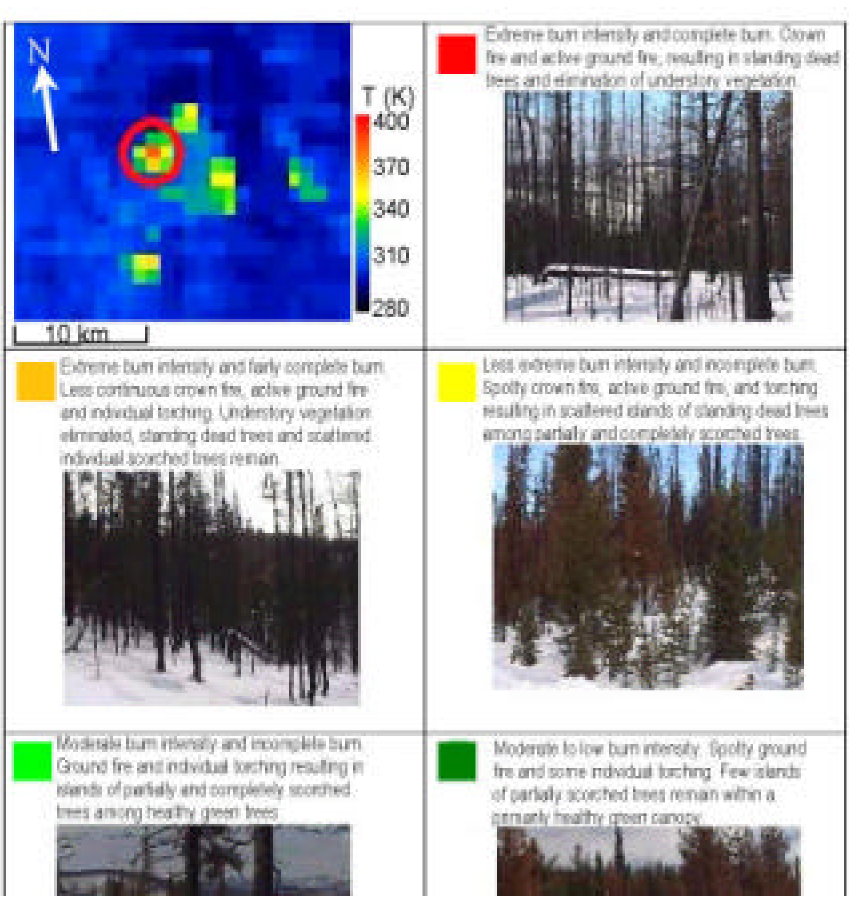


Fig. 5. Initial comparison of MODIS to Hazemeter AOT

The AOT data measured by MODIS and hazemeters are linearly correlated at both the 680/659 spectral band (R^2 = 0.781) and the 530/550 band (R^2 = 0.862). However, MODIS AOT data are about 50-60% lower than AOT data of hazemeters. The variation of AOT data from the linear equations might be caused by different spatial integrations of the two instruments. The MODIS instrument is looking down and the ground instruments are always looking up at the sun. If the atmosphere is inhomogeneous, this would cause problems. It would be valuable to characterize the atmospheric homogeneity by comparing the ground hazemeter readings at adjacent sites during satellite overpass. Another explanation is that the MODIS AOT algorithms may be dependent on the satellite's look-angle. We are currently investigating these two possibilities.

2.2 Radiative Energy in 2000 Montana and Idaho Fires

The biggest advantage of using the MODIS instrument for fire research, compared to other satellites, is that it is feasible to measure radiative energy produced by fires. We compared ground observations of fire extent with MODIS-derived radiative energy for fires in Montana on Aug. 23, 2000. The results are shown in the following figure. We concluded that high radiative energy was correlated with extreme fire intensity, resulting in dead trees and elimination of understory vegetation. Low radiative energy is related to moderate intensity fires, resulting from some understory fires and individual trees being torched.



2.3 Active Fire Locations and Burned Areas in the U.S.

We are acquiring the National Interagency Fire Management Integrated Database (NIFMID) and fire perimeter polygons to validate MODIS-derived active fire locations and burned areas. It takes considerable amount of time to obtain the data sets because they are not archived at a central location. Personal contacts had to be made to nine Regions of the Forest Service. We have acquired both data sources for fires in Montana and Idaho in August 2000. We have also acquired most of the NIFMID and some fire perimeter maps in the continental U.S. in 2001. After all the data sets are collected, we will compare active fire locations and burned areas derived from MODIS measurements and those obtained from the Forest Service ground and aerial surveys. Only the data after November 2001 will be used, because MODIS fire algorithms were revised at that time. Fig. 6 summarizes the locations of large fires in the U.S. in 2001. Fires in the eastern U.S. were mostly caused by human activities, and lightning caused most fires in the western U.S.

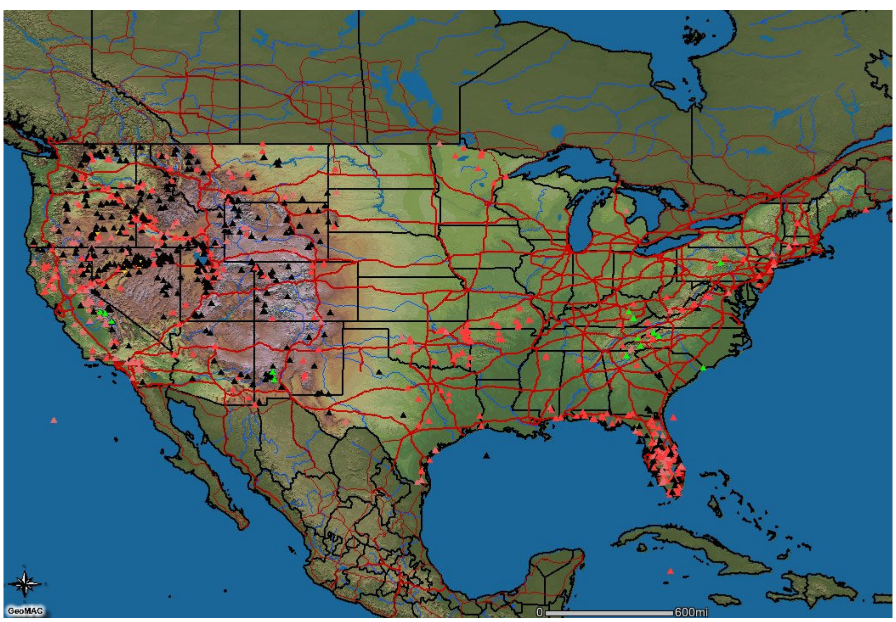


Fig. 6. Large fire locations in the U.S. in 2001. Fires caused by lightning (∏), and fires caused by humans (∏).

For some large fires, the Forest Service conducted aerial surveys of active fire fronts using airborne infrared cameras. There were about 100 aerial surveys conducted in 2001 and, for some large fires, active fire boundaries were monitored on multiple days. We have already acquired the fire perimeter polygons in the Northern Rockies, Intermountain Region, Pacific Northwest, and part of the Southwest. We are continuing to collect all the available data. Some of the fire perimeters in the southwestern U.S. in 2001 are shown in Fig. 7. We will compare MODIS-derived burn scars with fire perimeters obtained by the Forest Service aerial surveys as soon as both sets of data are collected.

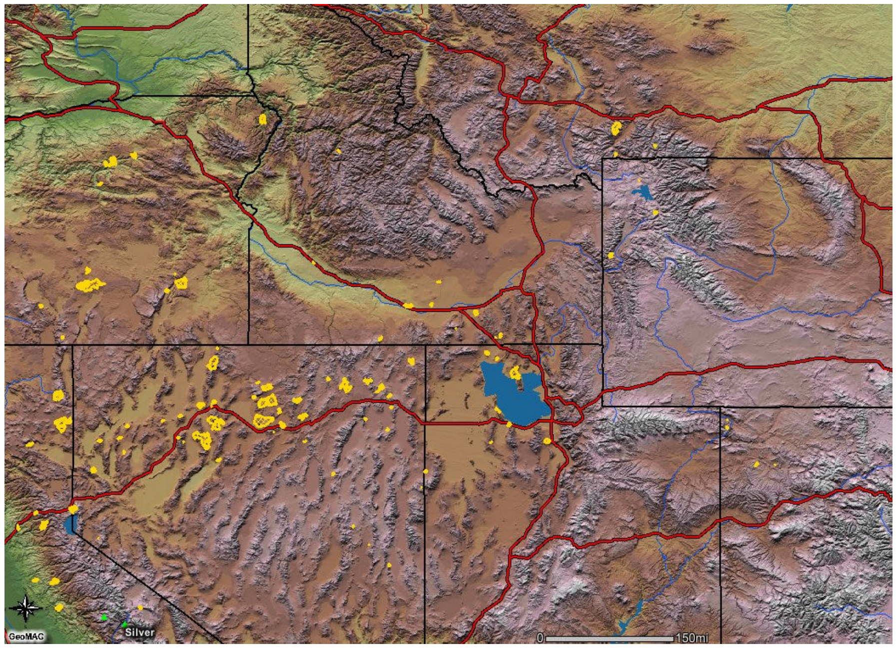


Fig. 7. Some fire perimeter polygons in southwestern U.S., 2001.

2.4 Aerosol light scattering vs. CO concentrations

During the SAFARI Campaign, we studied vertical and horizontal distributions of CO_2, CO, CH_4, and light scattering of aerosol particles in biomass smoke in Southern Africa from Sept. 12th to 24th, 2000.

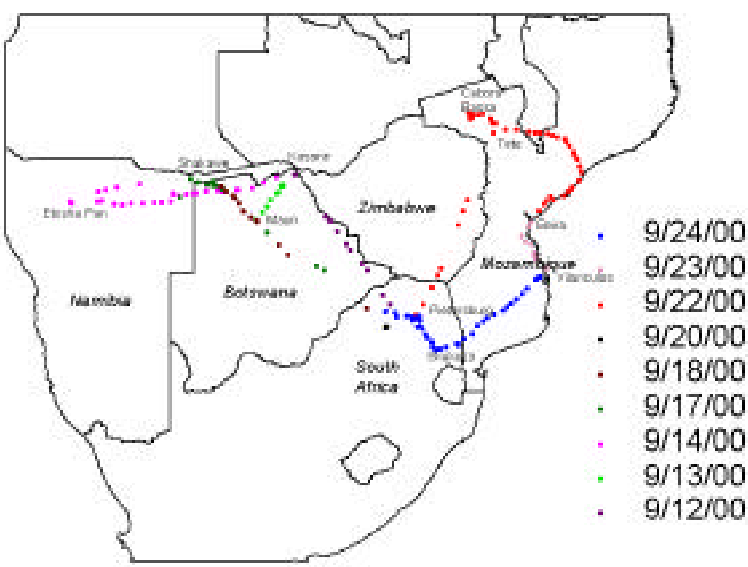


Fig. 8. Fight paths and canister sample locations during the SAFARI 2000 Campaign.

We measured integrated light scattering of aerosol particles and CO_2 in real-time and collected canister samples for trace gas measurements on the South African Weather Bureau's AeroCommander 690. The flight paths are shown in Fig. 8. In addition, we determined the chemical composition in smoke plumes and measured light scattering of aerosol particles in vertical profiles over the NASA AERONET sites in Etosha Pan, Namibia, Maun, Botswana, and Skukuza, South Africa. The results were presented at the American Geophysical Union Fall Meeting in San Francisco, December 2001.

The most important finding was that the light scattering of aerosol particles was linearly correlated with the CO concentrations in smoke plumes [Fig. 9]. Similar linear relationships were found from previous ground-based experiments of biomass burning in tropical and temperate ecosystems. We are currently studying the relationship between MODIS-derived AOT and MOPITT-derived carbon monoxide concentrations.

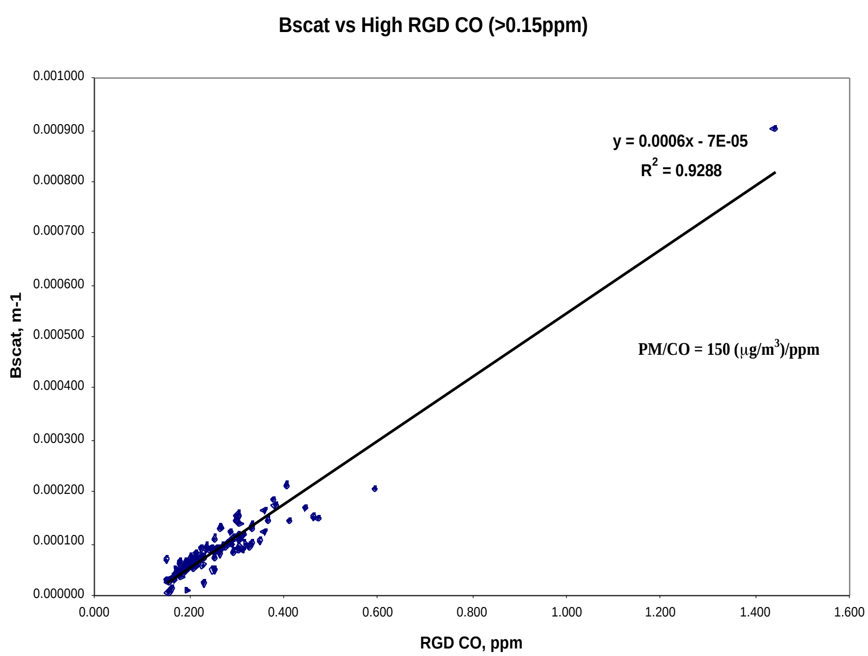


Fig. 9. Relationship between light scattering of aerosol particles and CO concentrations.

3. Future Research

The progress of this project is behind by about a year, because of the Terra launch delay, algorithm revisions, and delayed collection and analysis of field data. We will continue to validate the MODIS fire and smoke products in 2002. The major tasks will be

(1) to explain the discrepancies in AOT measurements among the MODIS, AERONET and hazemeters.
(2) to compare the AOT measurements made by the MODIS instrument, the hazemeters, and AERONET in Zambia in 2001.
(3) to compare the MODIS-derived radiative energy with calculated radiative energy based on fire behavior of selected large fires.
(4) to compare MODIS-derived active fire locations and burned areas with the Forest Service ground and aerial surveys of fires in 2001.
(5) to investigate the relationship between the AOT measured by the MODIS instrument and the carbon monoxide concentrations measured by the MOPITT instrument.